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THE CLINICAL SIGNIFICANCE OF PRECORDIAL LEADS IN THE DIAGNOSIS OF HEART DISEASE*

PART I

Precordial leads possess certain advantages in the diagnosis of heart disease but there are corresponding limitations. It is essential to interpretation that these be understood clearly. If they are, there is little reason, despite unsatisfactory gaps in knowledge, for the confusion complained of by many workers.

The differences of potential that develop among areas of the body surface during the heart beat are dependent on (1) bio-electric phenomena which are part of the process of activation of muscle fibers, (2) changes of potential at cardiac surfaces which result from them and (3) current flow between cardiac and body surfaces through tissues of varying structure and composition. Each of the three poses its own special set of thus far unsolved problems. We are therefore compelled, whether we like it or not, to make provisional assumptions on which to try to erect a science of electrocardiography.

Electrocardiograms in which one electrode is placed in close contact with the heart and the other at a distance

In this discussion, the conventional assumption is adopted that when an exploring electrode placed in contact with a part of a cardiac surface is paired with a distal electrode, the differences of potential recorded in an electrocardiogram in effect reflect the potential variations transmitted to the exploring electrode. Such an assumption obviously cannot be mathematically accurate, partly at least because of the demonstrable differences of potential among regions far from the heart. Furthermore it disregards the possibility that there may develop potential variation of ventricular origin common to all areas on which electrodes may be placed. Electrocardiography cannot explore this possibility. For example, practically uniform distribution of the mean potential variations of a body surface area throughout a second body can be achieved by good electrical contact between that area and any part of the second body, a phenomenon that could not even be suspected by any method of pairing electrodes on the second body alone.

Much of the great contribution of the late Sir Thomas Lewis to electrocardiography was made possible by the technic of placing one electrode on various parts of the epicardial and endocardial surfaces and the other at a distance. Nearly all that is now known regarding the significance of the deflections composing the QRS complex and much of what is known regarding the so-called RS-T segment and the T wave stem from his use of this technic. The relationships of variations of potential of ventricular surface and body surface are fundamental to an understanding of electrocardiography. For this reason, the ventricular phenomena recorded in cardiac surface leads will be reviewed briefly as a preliminary to the review of precordial leads. They can be most conveniently discussed under the separate headings of the QRS complex, the RS-T segment and the T wave. On the basis of the assumption mentioned previously, magnitude of potential variation responsible for an electrocardiogram is relatively great at cardiac surfaces and decreases rapidly as distance in the direction of a body surface increases.

The QRS complex.—The landmark of the QRS complex in leads made with one electrode in contact with a cardiac surface and the other at a distance from the heart is the intrinsic deflection.* Its components at the customary speeds of photographic paper are nearly perpendicular in slope and form a sharp peak. With the polarity now used, the first is upward in direction and the second is downward. Lewis called this deflection "intrinsic" presumably because it reflects electrical activity very near to the electrode placed on the heart. The upward component marks the course of the excitatory process from nearby regions, mainly from within outward to the myocardium directly under the electrode. It reflects a rise of potential in resting muscle external to the boundary of activation simultaneous with fall of potential at the external surfaces of the cells being activated. In normal hearts it is relatively larger over the left ventricle than over the right, presumably because the muscle wall is thicker.

The downward movement begins when activation of the subepicardial cells under the electrode has proceeded far enough to reverse the direction of potential variation transmitted to the electrode. As soon as this process is completed, the muscle under the electrode attains electrical equilibrium with all parts continuous with it and already activated so that potential variation transmitted to the electrode thereafter is a resultant of the further spread of the excitatory process. The potential is usually negative during this part of the QRS complex. Thus, if the downward component of the intrinsic deflection falls relatively early in the QRS complex it tends to extend far below the base line. If the electrode is on a part activated late, the downward movement will extend little or not at all below the base. Except over parts of the surface activated first where the QRS complex is initiated by the upward part of the intrinsic deflection there is recorded an early extrinsic movement. When this is downward (first limb of the Q deflection) according to Wilson it reflects the underlying

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*In this instance, "deflection" does not have the limited meaning of deviation from a base or reference line. The intrinsic deflection refers to the two components which form it, irrespective of their relationships to that line. For the analogous movements recorded in precordial leads the term "intrinsic-like deflections" has been used instead of "intrinsicoid" once applied by Wilson. Lewis sometimes wrote of the intrinsic deflection as though he were referring only to what is here called the downward component. This would not only conform more closely to the meaning of "intrinsic" but would permit the more accurate designation "pre-intrinsic" for the upward component and correspondingly terms for each of the analogous components in precordial leads. I have attempted such a nomenclature elsewhere than in this summary because it possesses the advantage of directing attention to the differences in the genesis of currents responsible for each.

endocardial potential. When it is upward it can be differentiated from the first part of the intrinsic deflection by its less steep slope. It probably reflects electrical activity at a distance proceeding in the general direction of the electrode.

Lewis demonstrated that the arrival of the intrinsic deflection on the side of the lesion in experimentally produced bundle-branch block is greatly delayed and also that it may be abolished completely by destruction of the tissue under the electrode. Wilson and his co-workers pointed out that if the muscle of a segment of the ventricular wall is destroyed by deprivation of its blood supply, the QRS complex obtained with an electrode placed over the surface takes on the characteristics of the potential of the endocardial cavity. These observations of Lewis and Wilson furnish the key to the understanding of the changes in the QRS complexes of precordial leads which point to intraventricular conduction defects or damage to the nonspecialized muscle of the ventricular wall or both.

The RS-T segment.—In animals used for experimental work such as dogs, there is usually little or no iso-electric interval between the end of the QRS complex and the beginning of the T wave as is frequently found in body surface leads in human beings, although the phenomenon called RS-T segment displacement is readily produced. No sharp dividing line between normal and pathologic segment displacement can be drawn. In experiments, the normal control for each lead must be established. The term "RS-T segment" is misleading. Whatever the mechanism responsible, if it is present it begins during the QRS complex, continues until the subsiding stage of the T wave and, during the times when it coincides with those deflections, is superimposed on them.

Pathologic RS-T segment displacement can be produced in a variety of ways, such as by acute deprivation of blood supply, trauma or the application of various chemical solutions. When the exploring electrode is placed directly on the surface involved, it is found that the direction of the displacement is positive. If, however, the region involved is anywhere else in the heart or even in the deeper layers of the wall directly under the electrode, segment displacement, if present, is negative.

The T wave.—When the surface of the canine heart is exposed to room air, the T wave in epicardial leads is frequently inverted and in leads made from the ventricular cavities under these circumstances, it is frequently upright. If care is taken to keep the animal in good condition and the cardiac surface uninjured, moist and at body temperature, the T wave is upright in epicardial leads and inverted in ventricular cavity leads. Moreover, if the thoracic cage is not opened and an exploring needle electrode, insulated except at the tip, is inserted near any part of the ventricular epicardial surface, the T wave is upright. It therefore seems probable that the T wave potential variation is normally positive over most if not all parts of the ventricular surface and negative within the cavities.

Slight injury or deprivation of blood supply insufficient to produce RS-T segment displacement may cause T wave changes. On the other hand it is possible to produce RS-T segment displacement by certain procedures such as the application of a dilute solution of ouabain without accompanying T wave change except that due to algebraic summation with the RS-T segment. It is probable that T wave changes produced by involvement of one part of the heart cause changes in the T wave potential of other parts just as in the case of the RS-T segment. The fact that the T wave potential of the ventricular cavities becomes positive when the epicardial surface is cooled illustrates this probability.

Precordial leads

Relationships to cardiac surface leads.—Precordial leads, although older than limb leads and used by Waller, Bayliss and Starling and Lewis for various purposes, became practically forgotten until 1932 when their clinical use for the diagnosis of acute coronary occlusion was pointed out. Shortly thereafter Wilson and his colleagues demonstrated that the order of ventricular excitation in bundle-branch block could be displayed by them. Since that time countless papers on precordial leads have been published but relatively few have dealt with the fundamentals of the subject.

In order to correlate what has been learned from cardiac surface leads with the findings in precordial leads of patients it is necessary to recognize both their similarities and their differences. Both reflect the potential variation of limited parts of the surface of the heart. This in turn is largely although not entirely determined by the electrical activity of regions of the heart very near those surfaces. In precordial leads, however, the competitive advantage possessed by a cardiac area in direct contact with an electrode is lost. Thus the potential variations not only of the area directly underlying the electrode but of adjacent areas as well are tapped. This difference can be illustrated by a simple experiment. If a sharply circumscribed region of injury involving the surface of the heart is produced, movement of a small exploring electrode a few millimeters across the margin of the injured region results in marked abrupt changes in the form of the electrocardiogram. Such abrupt changes can never be recorded in precordial leads. Nevertheless, as Wilson has pointed out, comparison of leads made with the exploring electrode placed (1) over the right side of the precordium and (2) directly on the underlying right ventricular surface shows definite resemblances; similar relationships also exist between the left side of the precordium and the underlying left ventricular surface. The fact that a single precordial lead reflects chiefly electrical activity of a limited part of the heart is the main reason for the necessity of more than one precordial lead.

Methods of pairing electrodes.—In precordial leads, unlike epicardial leads, the differences of potential among areas distant from the heart are relatively great enough that patterns may be influenced at least to some extent by potential transmitted to the distal electrode. Our interest in precordial leads is in the variations of potential of the precordial areas. Consequently the best method of pairing electrodes would be the one in which the potential of the distal electrode or electrode system remains most nearly constant during the heart beat. Methods that purport to accomplish this objective have to be based on assumptions. The term "unipolar leads" expresses a hope rather than an established fact, because there is at present no method of proving the unipolarity of an electrocardiographic lead that does not involve the acceptance of assumptions which still require evidence to establish their credibility. The better the method, the better will it be capable of displaying the relationships between cardiac surface and body surface variations of potential and probably of minimizing the differences between them. In the absence of general agreement as to the best method, further discussion will be based on the findings obtained when the exploring electrode is paired with one placed on the right arm (CR leads) or over the spine of the right scapula about halfway between the midline and the posterior axillary border. The differences between these two are never great.

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